

CLAIMS:

What is claimed is:

- 1 1. A method comprising:
 - 2 recording a plurality of write commands in a forward
 - 3 journal;
 - 4 generating a virtual recovery mapping object from
 - 5 the plurality of write commands, wherein the virtual
 - 6 recovery mapping object maps logical addresses into
 - 7 physical storage addresses;
 - 8 generating a plurality of backward moves from the
 - 9 write commands, wherein the backward moves correspond to
 - 10 reverse changes that reverse the effect of the plurality
 - 11 of write commands;
 - 12 correlating the virtual recovery mapping object with
 - 13 the plurality of backward moves so that the virtual
 - 14 recovery mapping object maps logical addresses to
 - 15 corresponding backward moves from the plurality of
 - 16 backward moves.
- 1 2. The method of claim 1, wherein the write commands
- 2 are atomic write commands.
- 1 3. The method of claim 1, further comprising:
 - 2 applying the plurality of write commands to a
 - 3 mirror-in-the-middle (MIM).
- 1 4. The method of claim 3, wherein the virtual recovery
- 2 mapping object maps a set of logical address ranges

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3 representing physical extents of data in the forward
4 journal into physical addresses of the physical extents.

1 5. The method of claim 3, wherein the virtual recovery
2 mapping object maps a set of logical address ranges
3 representing physical extents of data in the mirror-in-
4 the-middle (MIM) into physical addresses of the physical
5 extents.

1 6. The method of claim 3, further comprising:
2 copying an extent of data corresponding to each of
3 the plurality of backward moves from the mirror-in-the-
4 middle (MIM) into a backward journal; and
5 generating, in each backward move, a pointer to the
6 extent of data in the backward journal corresponding to
7 that backward move.

1 7. The method of claim 6, wherein the virtual recovery
2 mapping object is a tree data structure having tree nodes
3 and physical extent lists, the physical extent lists
4 represent extents of data stored in the backward journal.

1 8. The method of claim 7, wherein the tree nodes
2 represent logical address ranges.

1 9. The method of claim 8, wherein the logical address
2 ranges correspond to physical address ranges located on
3 the mirror-in-the-middle.

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1 10. The method of claim 8, wherein the logical address
2 ranges correspond to physical address ranges stored in
3 extents of data in the backward journal.

1 11. The method of claim 6, wherein each of the write
2 commands contains a logical address range, and generating
3 the plurality of backward moves includes identifying at
4 least a portion of the logical address range that is
5 mapped into an extent of data in the backward journal and
6 generating a backward move corresponding to the at least
7 a portion of the logical address range.

1 12. The method of claim 3, further comprising:
2 in response to applying the plurality of write
3 commands to the mirror-in-the-middle, removing the
4 plurality of write commands from the forward journal.

1 13. The method of claim 1, wherein the forward journal
2 includes a circular queue.

1 14. The method of claim 1, wherein the plurality of
2 backward moves is generated in response to a system
3 event.

1 15. The method of claim 1, wherein the plurality of
2 backward moves is generated at least one specified time.

1 16. The method of claim 1, wherein the plurality of
2 backward moves is generated in response to insufficient
3 space being available for the forward journal.

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1 17. The method of claim 1, wherein the virtual recovery
2 mapping object contains an indexed data structure that is
3 indexed on a first set of logical address ranges.

1 18. The method of claim 17, further comprising:
2 in response to the virtual recovery mapping object
3 exceeding a pre-determined size in memory, re-indexing
4 the virtual recovery mapping object to be index on a
5 second set of logical address ranges.

1 19. The method of claim 1, further comprising:
2 updating the virtual recovery mapping object in
3 response to a second plurality of write commands.

1 20. The method of claim 1, further comprising:
2 generating additional backward moves in response to
3 a second plurality of write commands.

1 21. The method of claim 1, further comprising:
2 updating a second virtual recovery mapping object
3 using the plurality of backward moves.

1 22. A computer program product in a computer readable
2 medium comprising functional descriptive material that,
3 when executed by a computer, enables the computer to
4 perform acts including:
5 recording a plurality of write commands in a forward
6 journal;
7 generating a virtual recovery mapping object from
8 the plurality of write commands, wherein the virtual

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9 recovery mapping object maps logical addresses into
10 physical storage addresses;
11 generating a plurality of backward moves from the
12 write commands, wherein the backward moves correspond to
13 reverse changes that reverse the effect of the plurality
14 of write commands;
15 correlating the virtual recovery mapping object with
16 the plurality of backward moves so that the virtual
17 recovery mapping object maps logical addresses to
18 corresponding backward moves from the plurality of
19 backward moves.

1 23. The computer program product of claim 22, wherein
2 the write commands are atomic write commands.

1 24. The computer program product of claim 22, comprising
2 additional functional descriptive material that, when
3 executed by the computer, enables the computer to perform
4 acts including:

5 applying the plurality of write commands to a
6 mirror-in-the-middle (MIM).

1 25. The computer program product of claim 24, wherein
2 the virtual recovery mapping object maps a set of logical
3 address ranges representing physical extents of data in
4 the forward journal into physical addresses of the
5 physical extents.

1 26. The computer program product of claim 24, wherein
2 the virtual recovery mapping object maps a set of logical

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3 address ranges representing physical extents of data in
4 the mirror-in-the-middle (MIM) into physical addresses of
5 the physical extents.

1 27. The computer program product of claim 24, comprising
2 additional functional descriptive material that, when
3 executed by the computer, enables the computer to perform
4 acts including:

5 copying an extent of data corresponding to each of
6 the plurality of backward moves from the mirror-in-the-
7 middle (MIM) into a backward journal; and

8 generating, in each backward move, a pointer to the
9 extent of data in the backward journal corresponding to
10 that backward move.

1 28. The computer program product of claim 27, wherein
2 the virtual recovery mapping object is a tree data
3 structure having tree nodes and physical extent lists,
4 the physical extent lists represent extents of data
5 stored in the backward journal.

1 29. The computer program product of claim 28, wherein
2 the tree nodes represent logical address ranges.

1 30. The computer program product of claim 29, wherein
2 the logical address ranges correspond to physical address
3 ranges located on the mirror-in-the-middle.

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1 31. The computer program product of claim 29, wherein
2 the logical address ranges correspond to physical address
3 ranges stored in extents of data in the backward journal.

1 32. The computer program product of claim 27, wherein
2 each of the write commands contains a logical address
3 range, and generating the plurality of backward moves
4 includes identifying at least a portion of the logical
5 address range that is mapped into an extent of data in
6 the backward journal and generating a backward move
7 corresponding to the at least a portion of the logical
8 address range.

1 33. The computer program product of claim 24, comprising
2 additional functional descriptive material that, when
3 executed by the computer, enables the computer to perform
4 acts including:

5 in response to applying the plurality of write
6 commands to the mirror-in-the-middle, removing the
7 plurality of write commands from the forward journal.

1 34. The computer program product of claim 22, wherein
2 the forward journal includes a circular queue.

1 35. The computer program product of claim 22, wherein
2 the plurality of backward moves is generated in response
3 to a system event.

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1 36. The computer program product of claim 22, wherein
2 the plurality of backward moves is generated at least one
3 specified time.

1 37. The computer program product of claim 22, wherein
2 the plurality of backward moves is generated in response
3 to insufficient space being available for the forward
4 journal.

1 38. The computer program product of claim 22, wherein
2 the virtual recovery mapping object contains an indexed
3 data structure that is indexed on a first set of logical
4 address ranges.

1 39. The computer program product of claim 38, comprising
2 additional functional descriptive material that, when
3 executed by the computer, enables the computer to perform
4 acts including:

5 in response to the virtual recovery mapping object
6 exceeding a pre-determined size in memory, re-indexing
7 the virtual recovery mapping object to be index on a
8 second set of logical address ranges.

1 40. The computer program product of claim 22, comprising
2 additional functional descriptive material that, when
3 executed by the computer, enables the computer to perform
4 acts including:

5 updating the virtual recovery mapping object in
6 response to a second plurality of write commands.

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1 41. The computer program product of claim 22, comprising
2 additional functional descriptive material that, when
3 executed by the computer, enables the computer to perform
4 acts including:

5 generating additional backward moves in response to
6 a second plurality of write commands.

1 42. The computer program product of claim 22, comprising
2 additional functional descriptive material that, when
3 executed by the computer, enables the computer to perform
4 acts including:

5 updating a second virtual recovery mapping object
6 using the plurality of backward moves.

1 43. A data management appliance comprising means for:
2 recording a plurality of write commands in a forward
3 journal;

4 generating a virtual recovery mapping object from
5 the plurality of write commands, wherein the virtual
6 recovery mapping object maps logical addresses into
7 physical storage addresses;

8 generating a plurality of backward moves from the
9 write commands, wherein the backward moves correspond to
10 reverse changes that reverse the effect of the plurality
11 of write commands;

12 correlating the virtual recovery mapping object with
13 the plurality of backward moves so that the virtual
14 recovery mapping object maps logical addresses to
15 corresponding backward moves from the plurality of
16 backward moves.

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1 44. The data management appliance of claim 43, wherein
2 the write commands are atomic write commands.

1 45. The data management appliance of claim 43,
2 comprising additional means for:
3 applying the plurality of write commands to a
4 mirror-in-the-middle (MIM).

1 46. The data management appliance of claim 45, wherein
2 the virtual recovery mapping object maps a set of logical
3 address ranges representing physical extents of data in
4 the forward journal into physical addresses of the
5 physical extents.

1 47. The data management appliance of claim 45, wherein
2 the virtual recovery mapping object maps a set of logical
3 address ranges representing physical extents of data in
4 the mirror-in-the-middle (MIM) into physical addresses of
5 the physical extents.

1 48. The data management appliance of claim 45,
2 comprising additional means for:
3 copying an extent of data corresponding to each of
4 the plurality of backward moves from the mirror-in-the-
5 middle (MIM) into a backward journal; and
6 generating, in each backward move, a pointer to the
7 extent of data in the backward journal corresponding to
8 that backward move.

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1 49. The data management appliance of claim 48, wherein
2 the virtual recovery mapping object is a tree data
3 structure having tree nodes and physical extent lists,
4 the physical extent lists represent extents of data
5 stored in the backward journal.

1 50. The data management appliance of claim 49, wherein
2 the tree nodes represent logical address ranges.

1 51. The data management appliance of claim 50, wherein
2 the logical address ranges correspond to physical address
3 ranges located on the mirror-in-the-middle.

1 52. The data management appliance of claim 50, wherein
2 the logical address ranges correspond to physical address
3 ranges stored in extents of data in the backward journal.

1 53. The data management appliance of claim 48, wherein
2 each of the write commands contains a logical address
3 range, and generating the plurality of backward moves
4 includes identifying at least a portion of the logical
5 address range that is mapped into an extent of data in
6 the backward journal and generating a backward move
7 corresponding to the at least a portion of the logical
8 address range.

1 54. The data management appliance of claim 45,
2 comprising additional means for:

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3 in response to applying the plurality of write
4 commands to the mirror-in-the-middle, removing the
5 plurality of write commands from the forward journal.

1 55. The data management appliance of claim 43, wherein
2 the forward journal includes a circular queue.

1 56. The data management appliance of claim 43, wherein
2 the plurality of backward moves is generated in response
3 to a system event.

1 57. The data management appliance of claim 43, wherein
2 the plurality of backward moves is generated at least one
3 specified time.

1 58. The data management appliance of claim 43, wherein
2 the plurality of backward moves is generated in response
3 to insufficient space being available for the forward
4 journal.

1 59. The data management appliance of claim 43, wherein
2 the virtual recovery mapping object contains an indexed
3 data structure that is indexed on a first set of logical
4 address ranges.

1 60. The data management appliance of claim 59,
2 comprising additional means for:
3 in response to the virtual recovery mapping object
4 exceeding a pre-determined size in memory, re-indexing

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5 the virtual recovery mapping object to be index on a
6 second set of logical address ranges.

1 61. The data management appliance of claim 43,
2 comprising additional means for:
3 updating the virtual recovery mapping object in
4 response to a second plurality of write commands.

1 62. The data management appliance of claim 43,
2 comprising additional means for:
3 generating additional backward moves in response to
4 a second plurality of write commands.

1 63. The data management appliance of claim 43,
2 comprising additional means for:
3 updating a second virtual recovery mapping object
4 using the plurality of backward moves.